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CRITERIA FOR THE HYDRAULIC DESIGN OF IMPACT BASINS  
ASSOCIATED WITH FULL FLOW IN PIPE CONDUITS

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## PREFACE

This technical release presents the recommendations on impact basins taken from the Bureau of Reclamation publication Hyd-572 - "Progress Report No. XIII - Research Study on Stilling Basins, Energy Dissipators, and Associated Appurtenances - Section 14, Modification of Section 6 (Stilling Basin for Pipe or Open Channel Outlets - Basin VI)" - dated June, 1969, by G. L. Beichley. These recommendations are presented here as criteria for impact basins associated with full pipe flow and pipe diameters from 1.5 to 5.5 feet, inclusive.

Using the ES-drawings included in this technical release, the proportioning of the impact basin and the riprap size may be obtained.

This technical release was prepared by John A. Brevard of the Design Unit, Design Branch at Hyattsville, Maryland.



TECHNICAL RELEASE  
NUMBER 49

CRITERIA FOR THE HYDRAULIC DESIGN OF IMPACT BASINS ASSOCIATED  
WITH FULL FLOW IN PIPE CONDUITS

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Engineering Standard Drawings

<u>Drawing No.</u>	<u>Title</u>
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ES-187	IMPACT BASINS: General Layout and Hydraulic Design
ES-188	IMPACT BASINS: Recommended Basin Widths for Various Pipe Diameters and Design Discharges
ES-189	IMPACT BASINS: Recommended Riprap Sizes





## NOMENCLATURE

A  $\equiv$  cross-sectional area of pipe, ft<sup>2</sup>

$$C = \frac{v_1}{D^{1/2}}$$

D  $\equiv$  pipe diameter, ft

$$F \equiv \text{Froude number} = \frac{v}{(g\sqrt{A})^{1/2}}$$

g  $\equiv$  acceleration of gravity, ft/sec<sup>2</sup>

Q  $\equiv$  design discharge, cfs

S  $\equiv$  minimum recommended D<sub>50</sub> riprap size, inches

v  $\equiv$  pipe flow velocity, ft/sec

v<sub>1</sub>  $\equiv$  flow velocity over the end sill, ft/sec

W  $\equiv$  basin width, ft

y  $\equiv$  vertical distance from top of end sill to top of riprap in channel bottom at end sill, ft

NOTE: See ES-187 for additional symbols and the terminology associated with various components of the impact basin.



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ASSOCIATED WITH FULL FLOW IN PIPE CONDUITS

Introduction

The Bureau of Reclamation has published three reports containing information on the hydraulic design of impact basins. The first was Hyd-399- "Progress Report No. II - Research Study on Stilling Basins, Energy Dissipators, and Associated Appurtenances" - dated June 1, 1955, by J. N. Bradley and A. J. Peterka. The second was Engineering Monograph No. 25 - "Hydraulic Design of Stilling Basins and Energy Dissipators" - dated September, 1958, by A. J. Peterka. This report was revised in July, 1963.

At the meeting of the SCS Committee for Standardization of Impact Basins in Denver, Colorado on March 7-9, 1966, the decision was made to accept the impact basin recommendations of Engineering Monograph No. 25 as the basis for formulating criteria for the hydraulic design of the Standard Impact Basins. The Standard Impact Basins were designed in accordance with this criteria.

The third Bureau of Reclamation publication concerning this subject is Hyd-572 - "Progress Report No. XIII - Research Study on Stilling Basins, Energy Dissipators, and Associated Appurtenances - Section 14, Modification of Section 6 (Stilling Basin for Pipe or Open Channel Outlets - Basin VI)" - dated June, 1969, by G. L. Beichley. This report gives the results of model studies of impact basins and recommendations for the hydraulic design of such basins. The study was deemed advisable because the operation of various prototype structures revealed a need for revision of the design standards of Engineering Monograph No. 25.

The recommendations in Hyd-572 differ somewhat from those given in Engineering Monograph No. 25; therefore, the layout for the SCS Standard Impact Basins does not agree completely with the latest recommended general layout as shown in ES-187. These differences are discussed below under General Layout.

The following are recommendations taken from Report No. Hyd-572. These recommendations are presented in this technical release as criteria for the hydraulic design of impact basins. The criteria given below is for impact basins associated with full pipe flow and pipe diameters from 1.5 to 5.5 feet, inclusive.

### Pipe Flow Velocity

The maximum pipe flow velocity,  $v$ , is 50 ft/sec. This limitation is imposed, because cavitation or impact damage to the basin may occur if this velocity is exceeded.

### Design Discharge

The design discharge used in selecting the impact basin width is determined using the minimum entrance loss coefficient for the inlet structure to the pipe. Use of the minimum entrance loss coefficient results in the highest discharges for the site conditions. The design discharge is the maximum discharge through the structure for the routing of the principal spillway hydrograph.

The maximum hydraulic grade line in the basin is assumed at  $d + f + t$  (see ES-187) above the basin apron. When determining the head for pipe flow computations, consideration of the location of the hydraulic grade line in the basin is necessary.

### Basin Width

The minimum impact basin width,  $W$ , is  $8/3$  of the pipe diameter,  $D$ . If  $W$  were made less than  $8 D/3$ , a portion of the flow jet for the design discharge would miss the baffle (see ES-187).

Drawing ES-188 which gives the relation of basin width,  $W$ , design discharge,  $Q$ , and pipe diameter,  $D$ , may be used to obtain the required basin width. This drawing is based on Figure 8 of Report No. Hyd-572. The equation of the line of Figure 8 was taken as

$$\frac{W}{\sqrt{A}} = 2.86F^{0.575}$$

where

$$A \equiv \text{Cross-sectional area of the pipe} = \frac{\pi D^2}{4}, \text{ ft}^2$$

$$D = \text{Pipe diameter, ft}$$

$$F \equiv \text{Froude number} = \frac{v}{(g \sqrt{A})^{1/2}}$$

$$g \equiv \text{Acceleration of gravity} = 32.16 \text{ ft/sec}^2$$

For particular values of  $D$  and  $Q$ , the proper basin width is that found from ES-188. When the point determined by the pipe diameter,  $D$ , and the design discharge,  $Q$ , lies between two Standard Impact Basin widths, select the larger basin width. If the basin is too large, the basin's effectiveness is reduced due to the jet passing under the baffle. Report No. Hyd-572 notes that "Since the basin will be larger than need be for less than design flows, the basin should not be oversized for the design flow."

### Pipe Slope

A horizontal length of pipe at least one pipe diameter long is required at the entrance to the basin. If the grade of the pipe near the basin exceeds 15 percent, the horizontal length must extend upstream from the basin at least three diameters. The horizontal length of pipe ensures that the jet for the design discharge fully impinges on the baffle.

### Riprap

Riprap is required on the channel bottom and side slopes for a distance of one basin width downstream from the end sill. The riprap on the side slopes of the channel must extend to the elevation of the top of the basin walls at the end sill. The minimum thickness of placed riprap is  $1/6$  of the basin width. A blanket of filter material or bedding, as required, is necessary beneath the rock riprap.

Drawing ES-189 is included to facilitate the determination of the required riprap size. At least half of the riprap by weight must equal or exceed the required riprap size.

### Tailwater

Tailwater is not required; however, tailwater depths up to a maximum depth of  $d + f/2$  (see ES-187) above the basin apron do reduce water surface roughness and bed erosion. Depths of tailwater greater than  $d + f/2$  above the basin apron should be avoided since these depths cause flow over the top of the baffle.

### Debris Protection

Report No. Hyd-572 states that "At some prototype installations, weeds and debris such as Russian thistles have been trapped in the basin between the pipe portal and the baffle. This debris has compacted to the extent of blocking the portal, thus reducing the capacity of the structure. The compacted weeds will not wash out and are very difficult to remove." Obviously, debris which is long and relatively rigid could also become lodged in the impact basin. Therefore, a Standard Covered Riser or an inlet which is equally effective in preventing entrance of debris is required when using an impact basin. Thus, an open top riser is not satisfactory in association with an impact basin.

For safety purposes and to prevent debris from entering the impact basin upstream of the baffle, a cover is required over the top of the basin between the pipe outlet and the baffle. The cover might be floor grating or precast concrete slabs placed with space between slabs to provide adequate basin ventilation. Secure fastening of the cover to the basin is necessary.

### General Layout

Drawing ES-187 shows the general layout of the impact basin as given in Figure 1 of Report No. Hyd-572. As mentioned previously, this layout differs somewhat from that used for the design of the Standard Impact Basins, ES-4000 series. These differences are:

1. The notches in the baffle are reduced in width and are moved a short distance from the sidewall to improve the flow conditions in the basin.
2. The height of the basin sidewall is increased to provide additional freeboard.
3. The distance,  $a$ , from the headwall to the baffle wall is  $W/2$ .



When a Standard Impact Basin is desired, the user has the option of using the drawings without change or of revising the drawings to conform with the general layout as given in ES-187. When an impact basin is desired which is not one of the Standard Impact Basins, the layout should conform to that of ES-187.

### EXAMPLE I

Given:

$$\begin{aligned} D &= 3.0 \text{ ft} \\ Q &= 150 \text{ cfs} \\ y &= 0.6 \text{ ft} \end{aligned}$$

Determine:

- I. The impact basin width.
- II. The recommended riprap size.

Solution:

- I. Determine the impact basin width.  
Using ES-188 and for  $D = 3.0 \text{ ft}$  and  $Q = 150 \text{ cfs}$ , read  $W = 12.25 \text{ ft}$ . Use a Standard Impact Basin with  $W = 13.0 \text{ ft}$ .
- II. Determine the recommended riprap size.

A. Compute

$$\frac{Q}{D^{5/2}} = \frac{150}{(3.0)^{5/2}} = \frac{150}{15.588} = 9.623$$

$$\frac{y}{D} = \frac{0.6}{3.0} = 0.2$$

- B. Using ES-189 and for  $Q/D^{5/2} = 9.623$  and  $\frac{y}{D} = 0.2$ , read  $C = 4.79$ .  
Then for  $D = 3.0 \text{ ft}$  and  $C = 4.79$ , read  $S = 16.0 \text{ inches}$ .

### EXAMPLE II

Given:

$$\begin{aligned} D &= 4.0 \text{ ft} \\ Q &= 550 \text{ cfs} \\ y &= 0 \end{aligned}$$

Determine:

- I. The impact basin width.
- II. The recommended riprap size.

Solution:

- I. Determine the impact basin width.  
Using ES-188 and for  $D = 4.0 \text{ ft}$  and  $Q = 550 \text{ cfs}$ , read  $W = 22.85 \text{ ft}$ . Use  $W = 23.0 \text{ ft}$ .
- II. Determine the recommended riprap size.

A. Compute

$$\frac{Q}{D^{5/2}} = \frac{550}{(4.0)^{5/2}} = \frac{550}{32.000} = 17.19$$

$$\frac{y}{D} = \frac{0}{4.0} = 0$$

- B. Using ES-189 and for  $\frac{Q}{D^{5/2}} = 17.19$  and  $\frac{y}{D} = 0$ , read  $C = 3.80$ .  
Then for  $D = 4.0 \text{ ft}$  and  $C = 3.80$ , read  $S = 13.85 \text{ inches}$ .  
Use  $S = 14.0 \text{ inches}$ .





STANDARD PLANS: STANDARD IMPACT BASINS  
SCHEDULE SHOWING DRAWING NUMBERS, VOLUMES  
OF CONCRETE, AND WEIGHTS OF STEEL.

STANDARD DETAIL DRAWINGS ES-4WWW	QUANTITIES*	
	STEEL - lbs.	CONCRETE - cu. yds.
ES-4050	1500	10
-4060	1900	12.5
-4070	2200	15
-4080	2800	20
-4090	3300	23
-4100	3900	28
-4110	4800	33
-4120	5700	38
-4130	6700	43.5
-4135	7300	46.5
-4140	7900	50.5
-4145	8800	55
-4150	10,000	58.5
-4155	10,600	62
-4160	11,000	65
-4165	12,400	70
-4170	13,300	73.5
-4175	14,100	77

Key to Drawing Numbers

The drawing numbers of the Standard Detail Drawings for Standard Impact Basins are given by:

ES-4WWW

where

WWW  $\equiv$  width of basin, WW.W ft

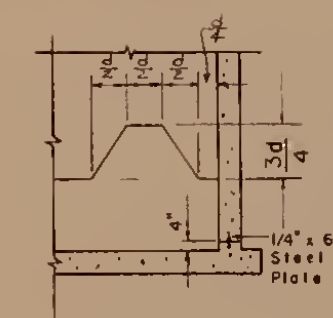
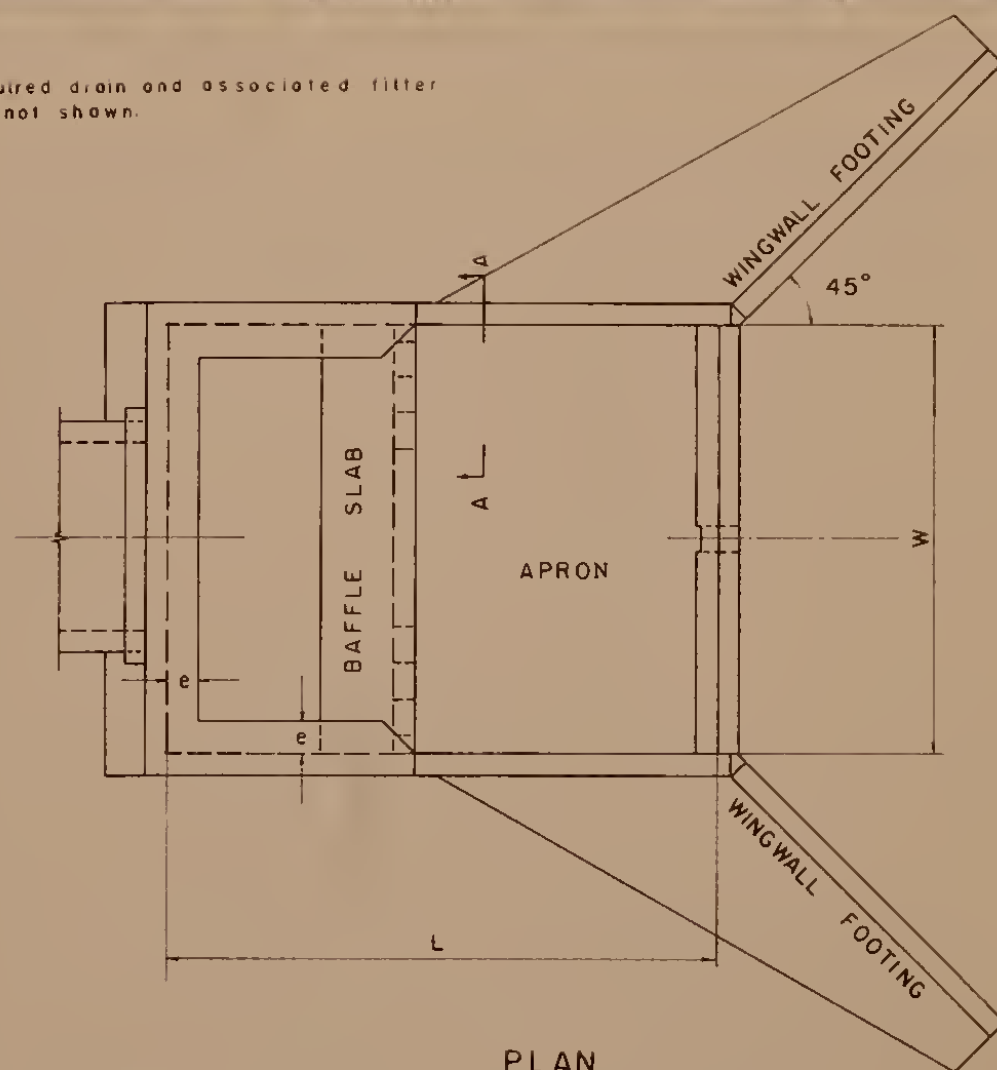
\*Quantities of steel and concrete tabulated were obtained from sheet 1 of each ES-drawing. These quantities are approximate since quantities vary with pipe diameter.

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE ENGINEERING DIVISION - DESIGN UNIT	STANDARD DWG. NO. ES- 186 SHEET <u>1</u> OF <u>1</u> DATE <u>5 - 70</u>
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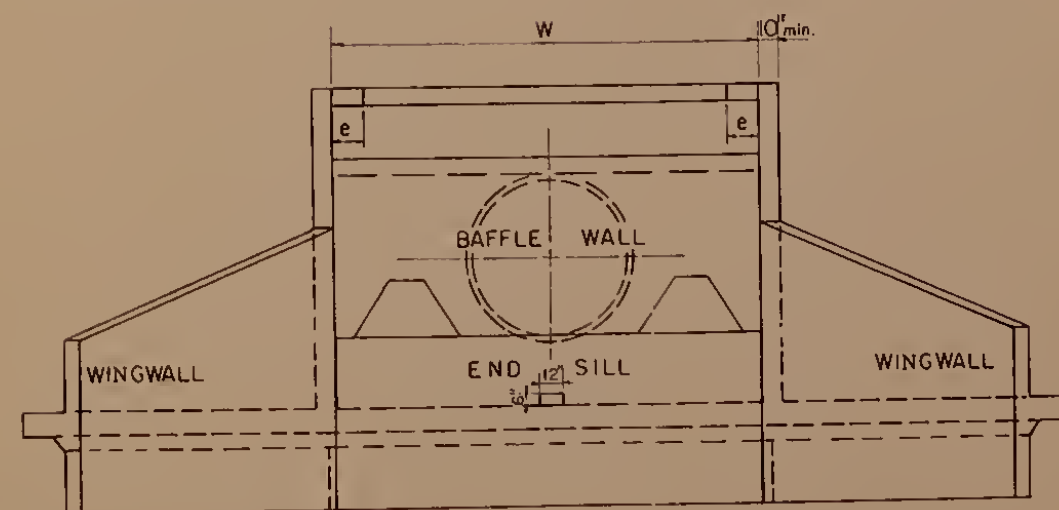
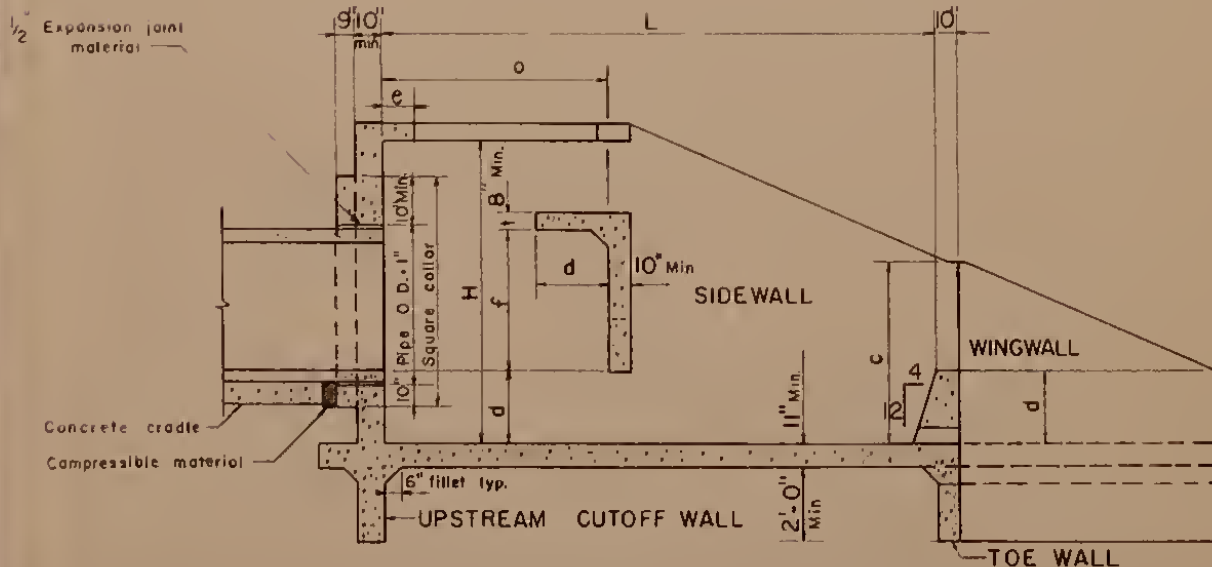
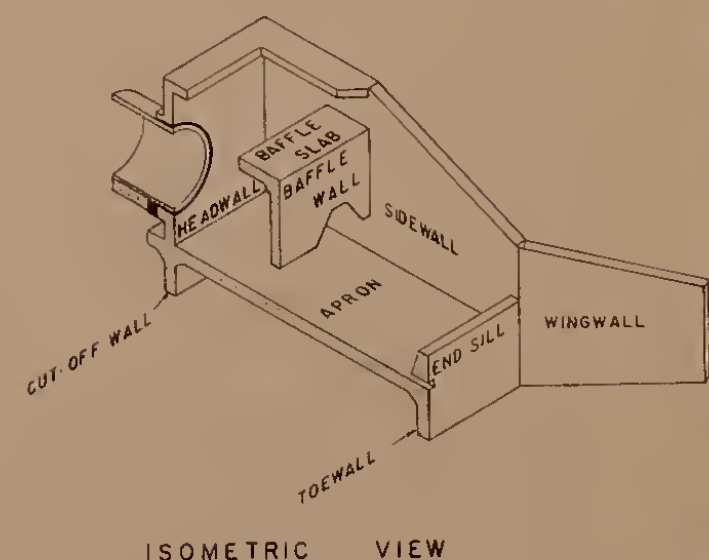
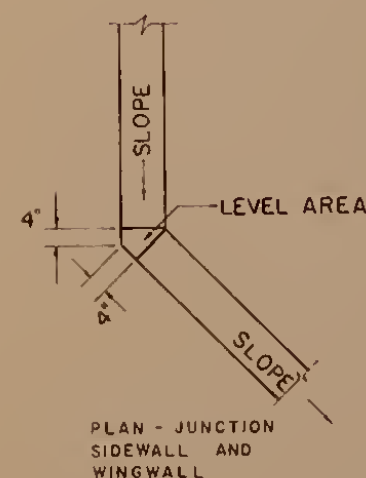
# IMPACT BASINS: General Layout and Hydraulic Design

Required drain and associated filter are not shown.



## SYMBOLS

W	=	Width of basin	=	4/3 W
L	=	Length of basin	=	3/4 W
H	=	Depth of basin	=	1/6 W
d	=	Height of end sill and height of pipe invert above apron slab	=	3/8 W
f	=	Height of baffle wall	=	1/2 W
a	=	Distance to upstream face of baffle wall	=	1/2 W
c	=	Height of sidewall and wingwall at junction	=	1/12 W
e	=	Width of splash brim	=	



## REFERENCE

Bureau of Reclamation, Report No. HYD-572, Progress Report No. XIII--Research Study on Stilling Basins, Energy Dissipators, and Associated Appurtenances--  
Section 14, Modification of Section 5 (Stilling Basin for Pipe or Open Channel Outlets--Basin VI)  
by G. L. Beichley

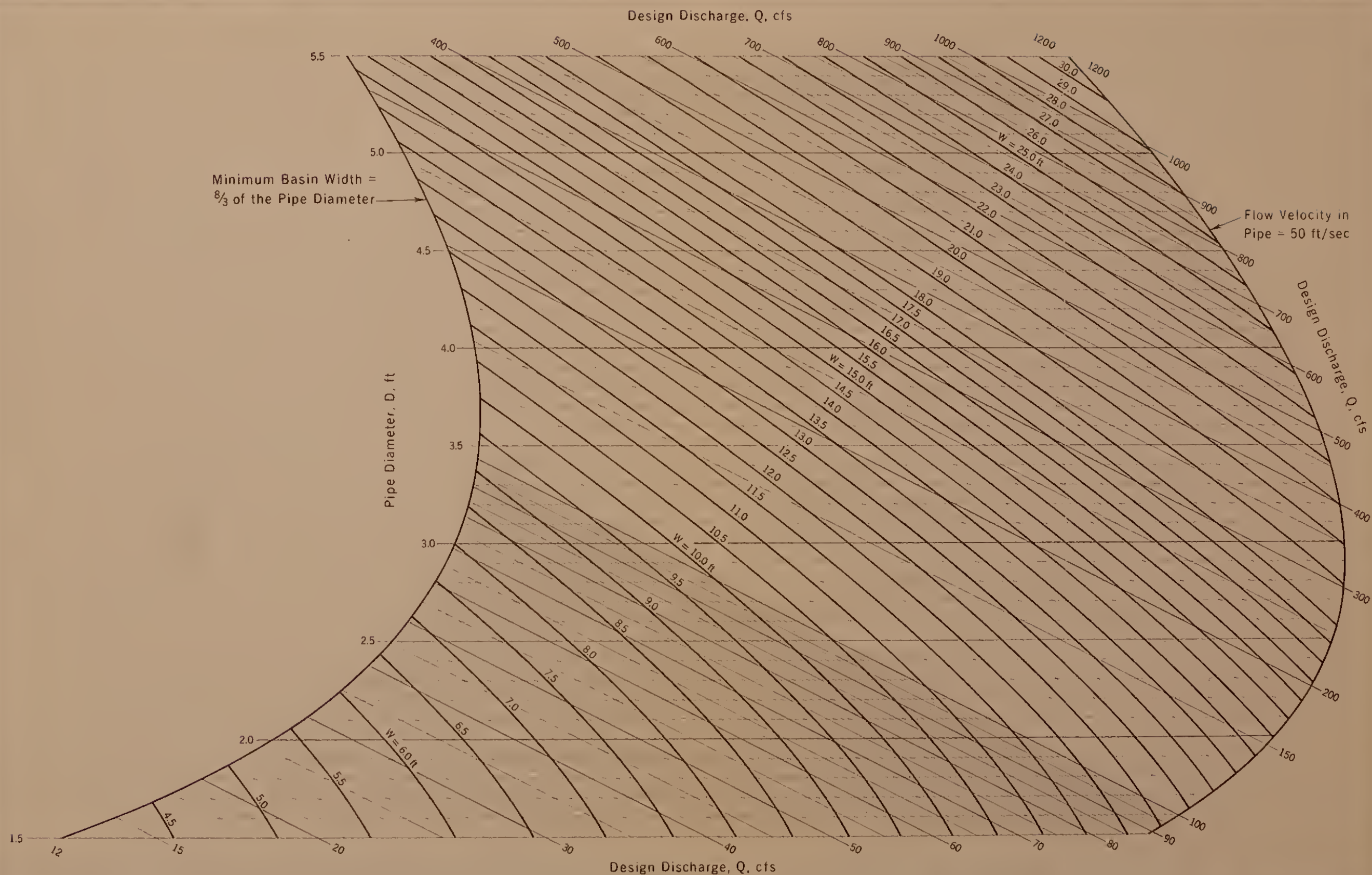
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ENGINEERING DIVISION - DESIGN UNIT

STANDARD DWG. NO.  
ES-187  
SHEET 1 OF 1  
DATE 12-70





# IMPACT BASINS: Recommended Basin Widths for Various Pipe Diameters and Design Discharges



## REFERENCE

Bureau of Reclamation, Report No. HY0-572, Progress Report No. XIII--Research Study on Stilling Basins, Energy Dissipators, and Associated Appurtenances--Section 14, Modification of Section 6 (Stilling Basin for Pipe or Open Channel Outlets--Basin VI)  
by G. L. Reichley

U. S. DEPARTMENT OF AGRICULTURE  
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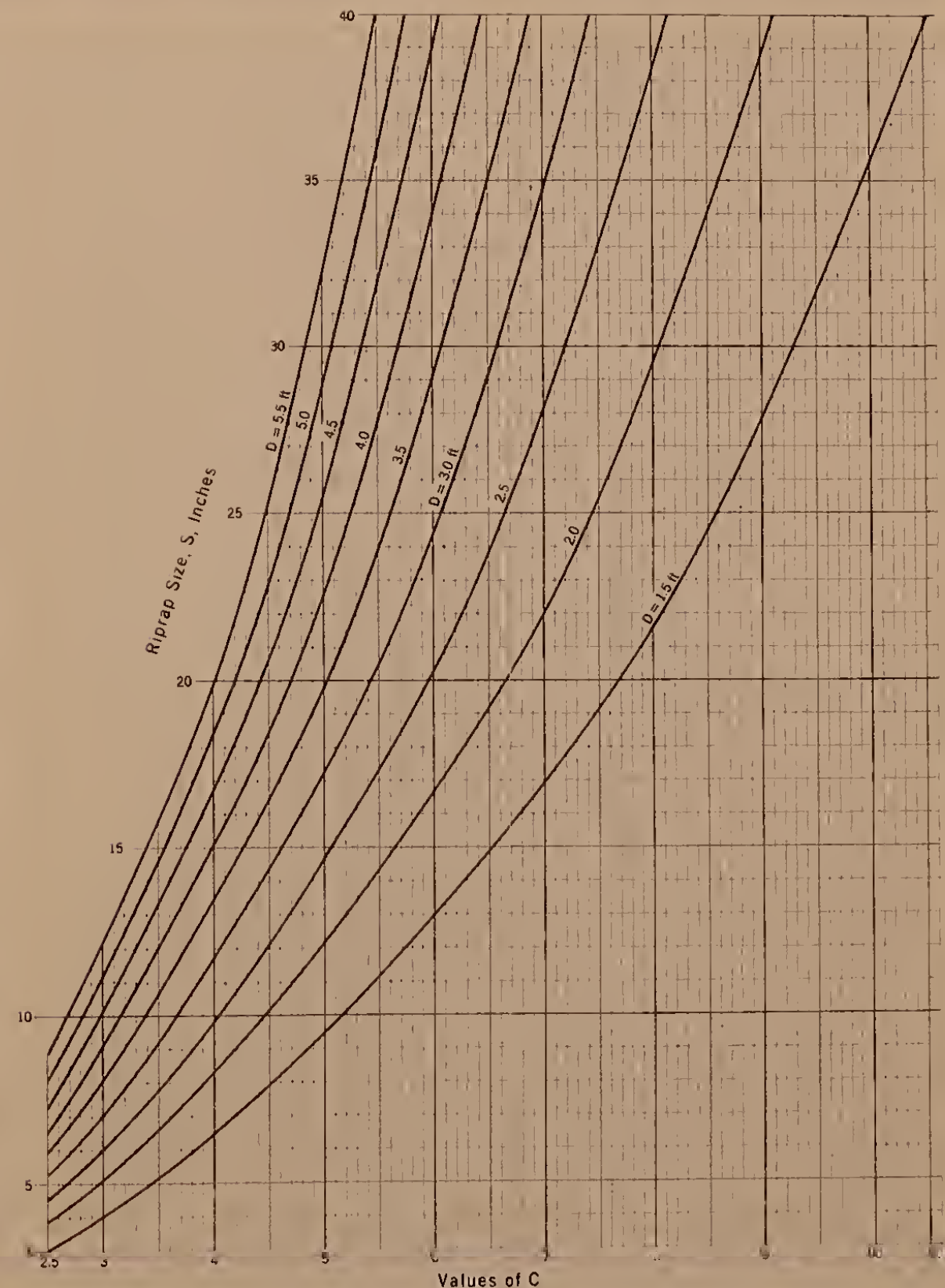
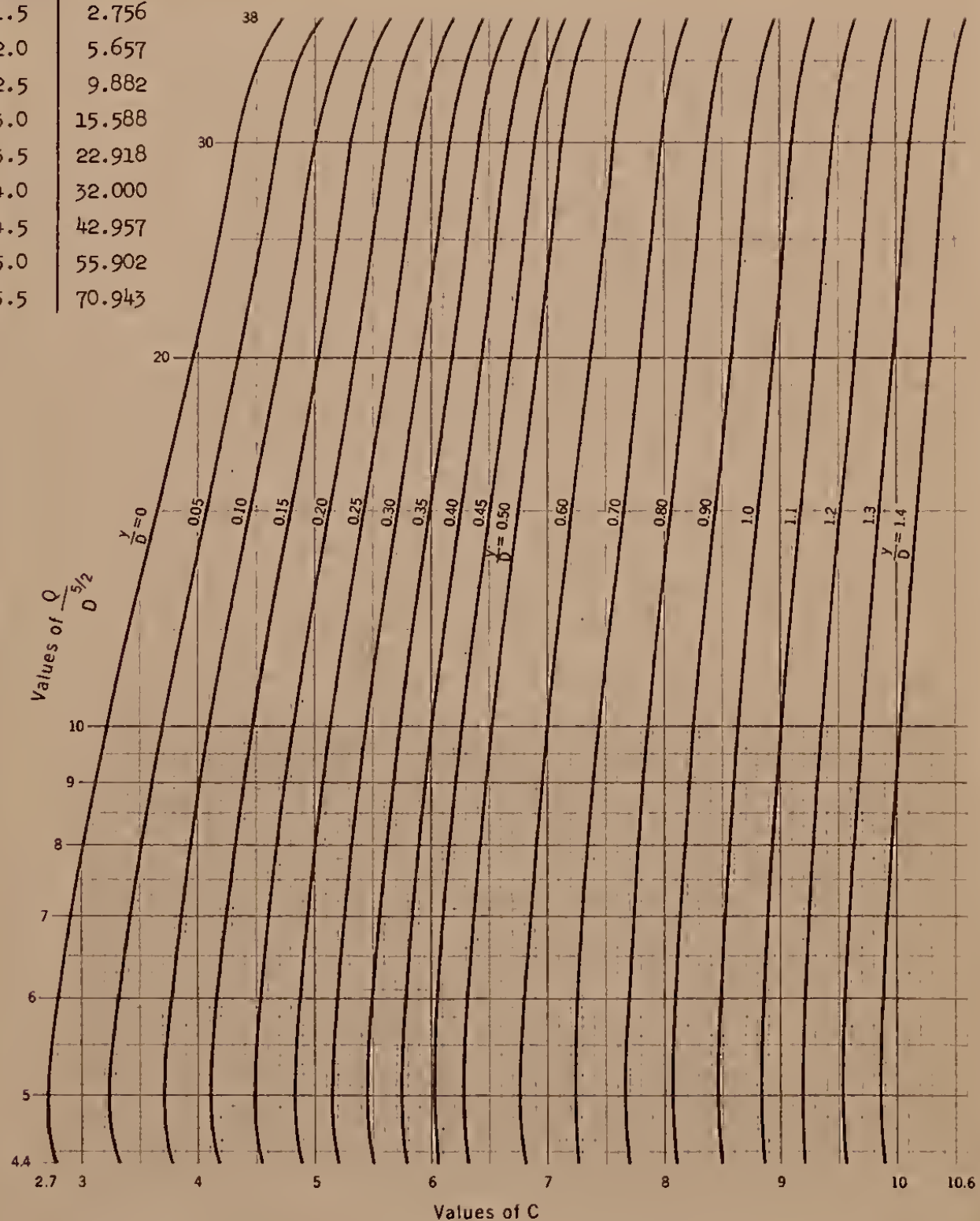
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ES 188  
SHEET 1 OF 1  
DATE 11-70





# IMPACT BASINS: Recommended Riprap Sizes

D, Ft	D <sup>5/2</sup>
1.5	2.756
2.0	5.657
2.5	9.882
3.0	15.588
3.5	22.918
4.0	32.000
4.5	42.957
5.0	55.902
5.5	70.943



## REFERENCE

Bureau of Reclamation, Report No. HYD-572, Progress Report No. XIII—Research Study on Stilling Basins, Energy Dissipators, and Associated Appurtenances—Section 14, Modification of Section 6 (Stilling Basin for Pipe or Open Channel Outlets—Basin VI) by G. L. Beichley

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